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INTERPRETATION OF ROCKET MEASUREMENT DATA OBTAINED IN THE UPPER ATMOSPHERE WITH THE HELP OF THERMOLUMINESCENT PHOSPHOR.

by

T. V. KAZACHEVSKAYA
G. S. IVANOV KHOLODNYY

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INTERPRETATION OF ROCKET MEASUREMENT DATA OBTAINED IN THE UPPER ATMOSPHERE WITH THE HELP OF THERMOLUMINESCENT PHOSPHOR *

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by T. V. Kazachevskaya
G. S. Ivanov-Kholodnyy

Measurements of the intensity of penetrating radiation in the lower part of the ionosphere, in the 70 — 100 km range were carried out aboard a rocket during the solar eclipse of 15 February 1961. with the aid of thermoluminescent phosphor $CaSO_4$ (Mn) [1]. - A very powerful radiation was then registered even during the maximum phase of the eclipse. A comparison between the radiation intensity measured with the aid of phosphoris with the effect that should have been anticipated from the X-radiation flux and from the emission in the L line, originating from the part of the solar corona not concealed by the Moon during eclipse, was made in reference [1]. It resulted, that signals from phosphorus were by two orders higher than might have been expected of X — or L_α - solar emission. That is why the interpretation of the obtained data requires further consideration.

T A B L E 1

Altitude Range km	Average height, km	$\Sigma_h \cdot 10^7$ qu. $cm^{-2} sec^{-1}$	Altit. range, km	Average height, km	Σ_h 10^7 qu. $cm^{-2} sec^{-1}$
58 — 72	66	11	94.8-87	91.2	2.4
94 — 96	95	3.1	87-76	81.5	1
96 — 94.8	95.5	6.8	76-55	67.5	<1.7 10^{-2}

* INTERPRETATSIYA DANNYKH RAKETNYKH IZMERENIY V VERKHNEY ATMOSFERE POLUCHENNYKH S POMOSHCH'YU TERMOLYUMINESTSENTNOGO FOSFORA.

The results of measurements of the sums of light Σ for various heights are compiled in Table 1. Certain peculiarities of the registered radiation must be noted. Its intensity at 95 km, expressed in the number of quanta of phosphor's emission Σ, constitues about $7 \cdot 10^7$ quantum cm^{-2} sec^{-1}. The radiation intensity drops with altitude decrease, and at 81 km it reaches $1 \cdot 10^7$ quantum cm^{-2} sec^{-1}. Therefore, with the altitude decrease by 14 km, which corresponds to about two heights of uniform atmosphere, the radiation intensity deceased less that should have been expected for a monochromatic emission. At 67 km it practically vanishes (its intensity decreases by more than 500 times in comparison with the intensity at 95 km).

Before passing to the interpretation of the results of measurements, let us consider other rocket experiments with phosphorus. A series of experiments were carried out in U.S.A. from 1948 to 1953 [2], in which a method different from that of [1] was applied. Phosphorus samples, exposed at a great height, were saved and de-excited in laboratory, which gave less reliable results. One of the advantages of the method of [2] consisted in that the exposure was effected with as well as without LiF, CaF_2 and Be - filters.

Let us examine the Table 2, in which are compiled the results obtained in [2]. Data on the conditions of the experiments are compiled in the first six columns: date, time, maximum height reached h_{max}; altitude range, effective exposure time t, surface of the phosphorus S. The last columns indicate the values of the sums of light Σ', measured by phosphorus through a LiF filter (transmitting L_α radiation) and without filter. phosphorus control sample signal ratios a, participating in the flight (which allows to account for the effect of phosphorus de-excitation in flight and to obtain the energy registered in absolute units), and also the converted values of the sums of light Σ.

TABLE 2

DATE	TIME	$h_{max.}$ km	h_{exp}, km	t, sec	S, cm^2	Σ', mca·sec LiF. filter	Σ', mca·sec NO filter	a	Σ, 10^7 quant. $cm^{-2} sec^{-1}$
18.XI.48	15.34	146	1-146-1	90	1.61	0.01	0.05	0.014	1.2
17.II.49	10.00	128	49-128-86	60	1.61	0.52	1.14	0.19	3.2
11.IV.50	15.05	88	54 - 88-17	30	0.65	0.008	0.034	0.23	0.38
17.II.50	11.00	150	19-82	1.5	0.65	0.012	0.073	dam.	0.1
17.II.50	11.00	150	82-127	3	0.65	0.126	5.84	0.79	10
17.II.50	11.00	150	127-148	3	0.65	dam.	8.87	0.91	8

It should be noted that in the experiment of 17 February 1950 the exposure time for phosphorus was of 50 sec, although the effective registration time of L_α radiation was only of 1.5— 3 s. on account of rocket spinning.

In order to compare the results brought out in Table 2 with the data obtained in the experiment [1], it is necessary to pass from sums of light Σ', expressed in microampere/sec, to the total number of quanta excited by phosphorus, as this was done in [1] (see Table 1). In this case we shall deal with quantities equally reflecting the intensity of the exciting radiation incident on phosphorus in both cases.

Let us determine the conversion factor for passing from microampere/sec units to the number of quanta for the intensity of L_α measured in [2]. To that effect, we shall make use of data of phosphorus) spectral sensitivity from [3], applied in [2], and also of the data on exposure time, the value of L_α absorption in the LiF filter (3 times), the surface of phosphorus sample and the relative dose of energy a remaining unexcited by phosphorus in flight (this according to data on phosphorus' control samples). It resulted then that according to data of the flight of 17 February 1950, the sum of light for the altitude range from 82 to 127 km, $\Sigma' = 0.126$ mka/s corresponds to L_α emission with a 0.048 watt cm^{-2}. According to data of the authors themselves [2], the intenisty of L_α emission during that flight was of 0.4 erg cm^{-2} sec^{-1}(thus practically the same), which, according to phophorus quantum yield [4], provides for the sums of light Σ the values $\Sigma = 10 \cdot 10^7$ quantum $cm^{-2} sec^{-1}$. It is timely to note, that the phosphorus sensitivity, brought up in [3], does not differ from that in ref. [4], which we actually used. Hence, we obtain that 1 microampere sec corresponds to $4 \quad 10^8$ quantum $cm^{-2} sec^{-1}$. The sums of light Σ', expressed in microampere sec, and registered by means of $Ca\ SO_4 (Mn)$ without filter, were converted into the values of the total number of re-emitted quanta $cm^{-2} sec^{-1}$, compiled in Table 2.

In connections with the considerations below, the total time of phosphoris exposure in the upper atmosphere, say 50 sec., was taken into account when computing Σ according to the 17 Feb.1950 experiment, and not the effective time of solar radiation registration.

The same conversion factor was used for the flights of 18 Nov. 1947, and for 17 February and 11 April 1949.

Originating from the data of Table 2, the following conclusions can be drawn. Note first of all, that at rather low altitudes, say to about 130 km, where only L_α-emission mainly reaches from the Sun, with a comparatively small amount of X-radiation, the signal from phosphoris without filter is by 1.5 — 2 times greater than the signal induced by L_α, whose intensity is estimated using phosphorus with the LiF filter. (*)- It is also confirmed by the same reasoning in regard to data of [2], that at altitudes below 130 km at least, a certain emission of considerable intensity and different from L_α, is being registered. It cannot be related to the effect of solar radiation in the region of the spectrum near L_α, for, according to latest spectroscopic data, the intensity of this emission constitutes only a few percent of that of L_α. Let us recall, that in our experiment [1] all ultraviolet radiation was concealed by the Moon.

(*) For 15 Feb.1950 it was 15 times greater. This was noted by the authors of [2] themselves. They ascribed the additional signal increase to the effect of emission in the 795 — 1050 Å range. It has however a low intensity and is strongly absorbed by the atmosphere, so that it can give a signal only above 130 km of about 0.4 erg $cm^{-2} sec^{-1}$ int. Since additional radiation was noted below 130 km, the explanation of [2] must be invalis.

Consideration of data of [2] shows, that when measuring with phosphorus, a powerful radiation was also registered. If we take into account L_α- emission (considering that it was absorbed in allcases by 3 times in the LiF filter), this radiation is equivalent to $4 - 9 \cdot 10^6$ quantum cm^{-2} sec^{-1} in the 80— 127 km altitude range (experiment of 17 Feb.1950), and at greater heights, as for the other three flights, in the 127— 148 km altitude range, the flux was about the same : $5 \cdot 10^6$ quantum cm^{-2} sec^{-1}. At 80 km (on 11 April 1949) and at 19— 82 km on 17 Feb.1950, the radiation is by about ten times weaker: $6 - 9 \cdot 10^5$ quantum cm^{-2} sec^{-1}.

These results, obtained in 4 different experiments, corroborate the fact itself of the presence of a radiation, not connected with the Sun, its great intensity and its value, measured during our own experiment [1] (see Table 1).

Therefore, a very powerful radiation was measured by means of phosphor — $CaSO_4$ (Mn),in [1], as well as in the American experiments [2]. On one hand, this radiation gives at 110 km a signal by one order of magnitude greater than in the 80— 95 km range, and on the other— it is observed at 70— 80 km, when L_α- emission is already strongly absorbed. The radiation registered by phosphorus cannot be monochromatic, but must have a comparatively broad spectrum. Among other things, it must include a component of a rather hard radiation, capable of penetrating to the 70 km level.

A radiation, similar in its characteristics to that described above, was observed earlier in the 70— 100 km altitude range, with the aid of thermoluminscent phosphor— ZnS (Ag) [5, 6]. This radiation was construed as corpuscular, consisting of electron fluxes. According to such measurements the energy flux of these electrons had in all the experiments a value of $(1-5)\ 10^{-2}$ erg cm^{-2} sec^{-1}. $ster^{-1}$. On the basis of ionospheric data, the spectrum and the intensity of this electron flux at various atmosphere levels in the

90 – 300 km altitude range, was computed in reference [7, 8]. Let us attempt to estimate the effect that may be caused by the action of this electron flux on the $CaSO_4$(Mn) phosphor.— The latter's sensitivity to electrons of various energies was measured by B. M. Nosenko, L. C. Revzin and al [9,10]. The sensitivity to electrons of energy E resulted equal to the sensitivity of phosphor X-ray radiation quanta with same energy.

The estimate of the effect from the electron flux may be conducted as follows. It was shown in the paper by L. A. Antonova and G. S. Ivanov-Kholodnyy [7] that electrons with energies of $8 \cdot 10^3$ and $1.5 \cdot 10^4$ ev reach respectively the 100 and 90 km levels in the atmosphere. The phosphor's sensitivity to such electrons is about equal to 10^9 quantum $\cdot$ erg^{-1}. Therefore, the intensity of electron flux at 95 km, according ot our measurements [1] during eclipse, constitutes 0.06 – 0.07 erg cm^{-2} sec^{-1}, which agrees well with the measurements of electron fluxes with the aid of ZnS(Ag)-luminescent phosphor : 0.01 – 0.05 erg cm^{-2} sec^{-1}.

Thus, the new measurements, conducted with the aid of $CaSO_4$(Mn) thermoluminescent phosphor during the solar eclipse provided important results, corroborating the earlier obtained data with the aid of ZnS (Ag) about the fact, that at 80 – 95 km, powerful electron fluxes are present. However, the described experiment is so far the first experiment of electron registration with the help of thermoluminescent phosphor and it is necessary to repeat similar measurements in the future.

**** THE END ****

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